Spang

A

PRACTICAL TREATISE

W. H. Wahl

ON

LIGHTNING-CONDUCTORS.

EXPLAINING THE DEFECTS OF THE LIGHTNING-CONDUCTORS NOW ERECTED, AND SHOWING HOW METAL ROOFS, OR SHEET-METAL BANDS BENEATH WOODEN OR SLATE ROOFS, AND THE ORDINARY RAIN-PIPES, WILL PREVENT BUILDINGS FROM BEING DESTROYED OR DAMAGED BY LIGHTNING DISCHARGES.

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With Illustrations.

PHILADELPHIA:
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PREFACE.

THE following treatise is an improvement upon that portion of my work on Lightning Protection, issued last year, which relates to the protection of buildings, as it contains more complete and explicit directions for applying metallic conductors, and particularly to wooden, slate, gravel, and Mansard roofs, steeples, towers, and barns.

It is issued with a view of effecting a general introduction of my improved and patented system of lightning-conductors, herein described, and thereby enabling property owners to obtain proper protection from lightning discharges at a moderate expense. The said system of lightning-conductors is highly recommended by the most prominent electricians and scientists, and will eventually supersede the expensive and unreliable lightning-conductors heretofore employed, and now erected, many of which have no less than four serious defects.

READING, PENNA., July, 1878.

HENRY W. SPANG.

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PRACTICAL TREATISE

ON

LIGHTNING-CONDUCTORS.

Lightning and Thunder.

DRY air is a poor conductor and concentrator of electricity, while moist air has considerable conducting and concentrating power.

When there is a sudden change of temperature, which generally occurs after a long dry spell, there is a sudden and great condensation of the aqueous vapor in the atmosphere, and a large accumulation of electricity in the dense masses of condensed vapor, which are known as thunder-clouds.

The electricity in a thunder-cloud, by a peculiar influence known as electric induction, decomposes and separates the combined electricity contained in the surface earth and every object over which it passes, repelling the electricity of the same phase, and attracting that of the opposite phase.

When the attraction between the positive electricity of a cloud and the negative electricity of the earth, or *vice versâ*, is able to overcome the resistance offered by the intervening air, a rushing together and uniting of the said opposite electricities takes place, which is known as a discharge, and effects the restoration of equilibrium between the said electricities. Discharges also take place between the opposite electricities contained in two clouds or layers of a cloud.

Lightning is the name given to the illuminating or vivid flash of light produced by the said discharges. The light we see is the effect of a discharge, and is due to the resistance offered by the atmosphere to the passage of electricity. The greater the resistance offered by the air, the greater is the heat developed, and more distinct is the light.

The electricity rushing with great rapidity, causes the air to be thrown into vibrations, producing the violent report and rumbling noise known as thunder.

Lightning and thunder are almost simultaneous, but an interval of several seconds is always observed between them, which arises from the fact that sound only travels at the rate of about 1100 feet per second, while the passage of light is almost instantaneous.

The Origin and Proper Function of the Lightning-Conductor.

The celebrated American philosopher, Benjamin Franklin, was led to the idea of the lightning-rod or conductor by the tendency that lightning discharges have for lodging on the tops of the spires of churches and masts of ships — in fact, all projecting bodies pointing toward thunder, or rather electrified clouds.

During the year 1749 he made a series of experiments with a Leyden jar (a device employed for greatly accumulating the electricity generated by a friction electrical machine), by which he found that pointed metallic conductors gave off and received electricity with great rapidity, and when the electricity in the jar was discharged by means of a sharp point, there was not that snapping spark which occurs when the jar is discharged by a ball or the blunt end of a rod.

After detailing the results of these experiments in a communication to P. Collinson, Esq., of London, England, under date of July 29th, 1750, he says: "If these things be so (referring to the discharging power of points), may not the knowledge of this power of points be of use to mankind in preserving houses, churches, ships, etc., from the stroke of lightning, by directing us to fix on the

highest points of these edifices upright rods of iron, made as sharp as a needle, and gilt to prevent rusting, and from the point of these rods a wire run down the outside of the building into the ground, or down round one of the shrouds of a ship, or down her side till it reaches the water? Would not these points probably draw the electrical fire silently out of the cloud, before it came nigh enough to strike, and thereby secure us from that most sudden and terrific mischief?"

Instances can be cited where there has been a diminution of lightning discharges after the application of lightning-conductors to the spires of churches and other high structures.

It has, however, been fully demonstrated that, owing to the long distance of most of the thunder-clouds from the earth, and their great area, a lightning-rod or conductor with one or more points at its top, also points along its entire length, cannot, as a rule, perform the function, suggested by Franklin in 1750, of silently tapping the electricity contained in a cloud and preventing lightning discharges taking place in the vicinity of the building, and particularly one of the ordinary height, to which it is applied.

The fact that lightning discharges have quite frequently taken place between thunder-clouds and the tops of lightning-conductors erected upon some of the highest steeples in the world, and which were well connected with the earth, is sufficient evidence that thunder-clouds are generally very high.

The distance between the lower part of thunder-clouds and the earth has been found to vary from 600 to 26,000 feet, according to the topography of the country and other circumstances. In this country, the average height of the said clouds above the earth is estimated at 2500 feet. It is only in the so-called cloud-burst, a tornado or rotary storm, that the cloud reaches the earth and then produces pitchy darkness.

As the equilibrium between the electricity contained in dense and high thunder-clouds and that contained in the earth can only be fully restored by lightning discharges, it is evident that the true object and proper function of the lightning-conductor consists simply in furnishing a better path for the passage of the electricity

from the clouds to the earth, or *vice versâ*, than the path offered by the objects which we wish to protect.

The electricity in a lightning discharge will invariably take the easiest path, or, as electricians say, the line of least resistance. If the resistance offered by the material and contents of a building is equal to the resistance offered by a metallic conductor, poorly connected with the earth, one-half the electricity in a lightning discharge will pass over the building and its contents, and the other half over the metallic conductor to the earth. In order to properly protect a building and its contents and inmates, it is absolutely necessary that the metallic conductor or path be made many times the better path, so that the greater portion of the electricity in a lightning discharge will pass over it and readily unite with the electricity of the earth, and such portion thereof as may pass over the brick, wood, and other material of which a building is constructed, would be so small as not to cause any damage thereto or be perceptible to its inmates, the said material being a conductor to a certain extent to the electricity in a lightning discharge.

Defects of the Lightning-Conductors now Erected.

In determining the requirements of lightning-conductors, the manufacturers and erectors have, erroneously, been governed by the properties of galvanic and ordinary frictional electricity, and have neglected to thoroughly investigate the peculiar properties of the electricity of the atmosphere and earth, and the lightning discharges which take place between them. The result is, many of the lightning-conductors now erected have no less than four serious defects, and consequently will not effect proper protection.

Galvanic electricity has a medium quantity — the term used for indicating the amount of electricity present — and a low potential or tension — the term employed for indicating the property or function of electricity which determines its motion from one point to another. In the electricity generated by ordinary friction, the quantity is small and the potential high, while the electricity of the

air, when in motion, as in a zigzag or rather spiral lightning discharge, combines great quantity with a very high potential, and is capable of producing effects which cannot be obtained by galvanic or ordinary frictional electricity.

An artificial electrical discharge, produced by a Ruhmkorff coil or Holtz machine, can barely pass through two feet of air or several inches of glass, while a lightning discharge can readily pass through two miles of air and twenty feet of solid rock.

Most of the lightning-conductors now erected contain a rather small quantity of metal, and are not able to properly resist the heating effect of the electricity in a heavy lightning discharge.

The weight of the wire cable, spiral twisted, and other peculiar and unscientifically formed conductors, varies from .16 to .48 of a pound per lineal foot, and the conductivity of most of them to the electricity in a lightning discharge is about equal to that of a round iron rod $\frac{5}{16}$ inch in diameter, which is not sufficient for safely conveying a very heavy charge of electricity, and fully resisting its heating effect. The quantity of metal should not be less than that contained in a round iron rod $\frac{7}{16}$ inch in diameter, which weighs .50 of a pound per lineal foot.

In a zigzag lightning discharge between a cloud and the earth, an immense quantity of electricity is concentrated, the atoms of which repel each other with great energy, giving rise to a great expansive action and mechanical force, and also creating an affinity for any object or objects over which the said electricity can readily spread out. A lightning discharge will invariably alight upon a large assemblage of persons, a herd of cattle, a large mass of hay, grain, ice, powder, or other material of medium conductivity, and particularly a large metal mass, like a tinned iron, or other metal roof, gas-holder, or an oil-tank, when beneath a thunder-cloud, for the reason that they offer a wide scope for the great expansive action of the electricity contained in the discharge.

The round iron rods, wire cables, spiral twisted and other forms of lightning-conductors now erected are too concentrated, and will not allow the electricity in a lightning discharge to have a proper scope for its great expansive action, and consequently the electricity

will not confine itself to the said conductors, but will leave them for the buildings to which they are attached.

The electricity in a lightning discharge has also a strong downward tendency towards the earth, and will not follow a metallic conductor when it is in a long horizontal, or indirect route between the points of the discharge.

The arrangement of conductors shown by the heavy lines along the ridges, gables, and eaves of the roof of building in Figure 1 is defective, and will not afford proper protection to the roof. It is recommended by Prof. John Phin, in his work on Lightning-Rods, and is an illustration of the ignorance heretofore shown by scientists on the subject of lightning protection.

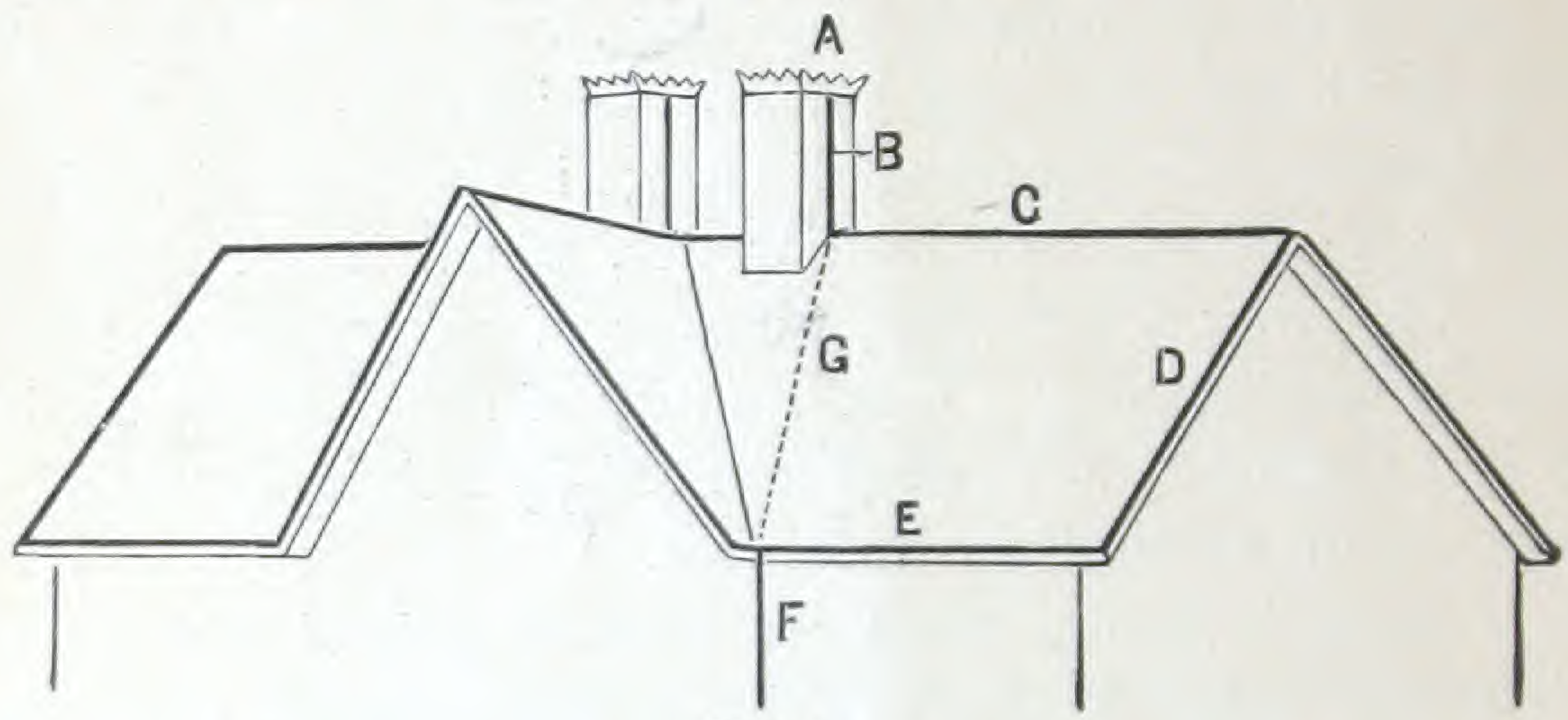

Fig. 1.

A lightning discharge taking place in line with the pointed metallic coping, A, upon the top of the right-hand chimney, is expected to follow the indirect route *via* the metallic conductors C, D, and E along the ridge, gable, and eave of the roof between the chimney conductor B and the vertical conductor F, which leads from the eave of the roof to the earth, while really it will take the more direct route, shown by the dotted line G, over the wooden rafters and sheathing of the roof between the conductors named. A large iron ball projected from a cannon with great force, might as well be expected to take such an indirect route.

The routes of many of the lightning-conductors now erected are very indirect, and particularly along the roofs of buildings, and consequently they will not effect safe passages for the electricity in lightning discharges.

In addition to the improper construction and application of lightning-conductors to buildings, they have not been placed in the earth to a suitable depth, thereby preventing the electricity from the clouds from readily uniting with the electricity of the earth, which is principally accumulated in the subterranean water-bed and not in the surface earth, as has been generally supposed. Many of the conductors now erected terminate in the earth from two to seven feet, alongside the foundation walls of buildings, as shown in Figure 2, and have, on an average, a metal surface of only eight inches square in contact with the earth.

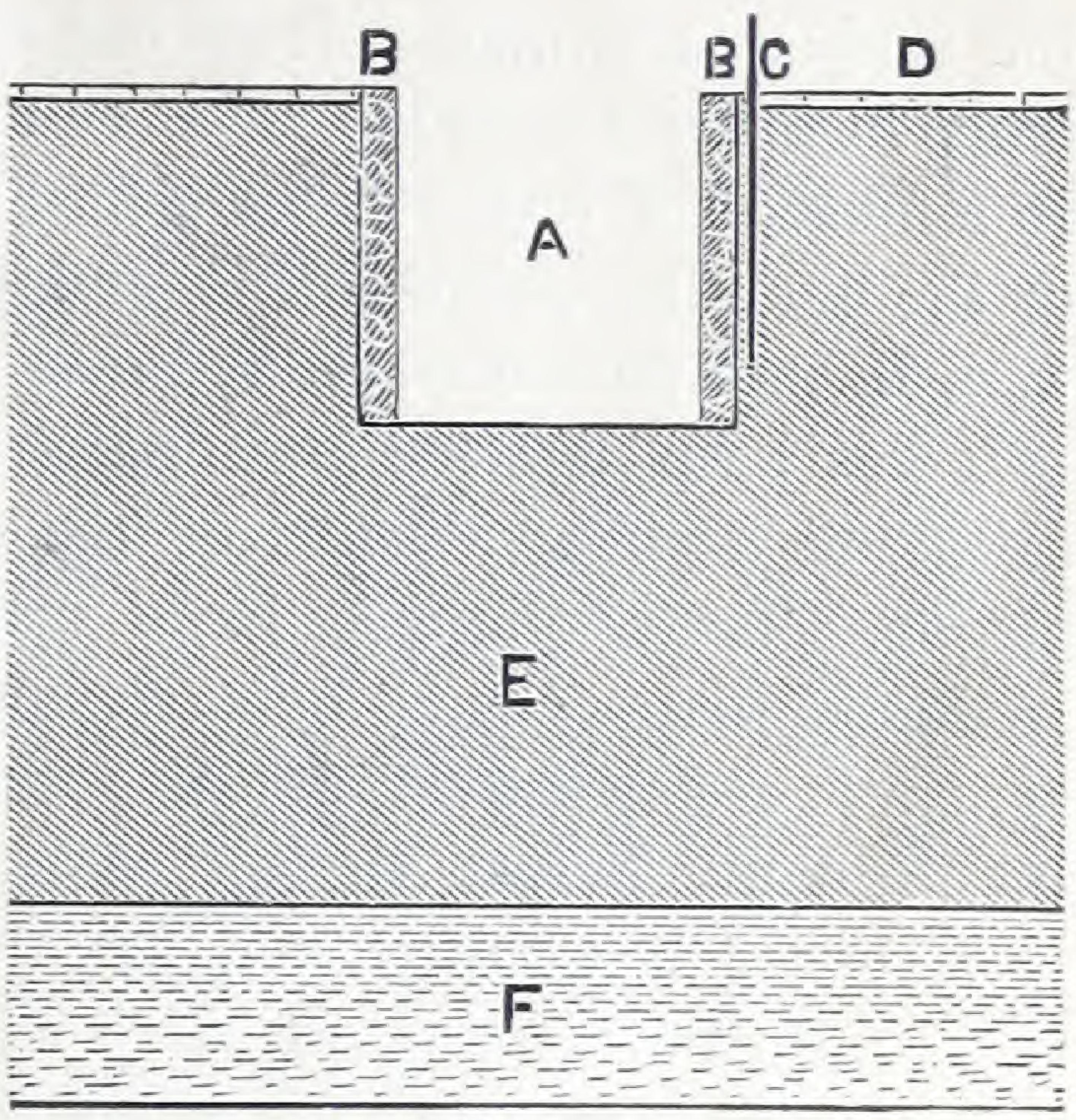

Fig. 2.

It has generally been supposed that at the depth of about six feet the earth adjacent to a building is in a moist condition during the summer season; but such is not the case. Rain is generally prevented by the building from falling near the foundation walls, and by the pavement, D, from penetrating the earth to a suitable depth, and, owing to the long intervals of rain and the excessive heat of the sun, the small quantity of rain that may have entered the earth near the lightning-conductor, C, during a summer shower is soon afterwards dried up. The earth, E, beneath the cellar, A, and pavement, D, is kept in a rather dry condition for a considerable depth, which together with the poor conductivity of the stone wall, B, greatly impedes the passage of the electricity in a lightning discharge between the conductor, C, and the subterranean water-bed or permanent moisture, F, and also prevents its expansive action from having a proper and easy scope in the earth.

If a river is dammed or cut off from shore to shore, except a single passage about a foot wide, there will naturally be a great

obstruction to the current thereof; a great accumulation of water will take place, which can only find a suitable outlet to the water below the dam by overflowing the adjacent territory or violently breaking away the dam. A similar but more violent effect takes place when the electricity from a cloud alights upon a metallic or lightning-conductor, the lower end of which is disconnected from the earth or is separated from the subterranean water-bed or permanent moisture by dry earth or solid rock. The said electricity being greatly retarded in its passage, is compelled to seek some other outlet, and it invariably leaves the metallic conductor above the surface earth, and spreads out over the building and its contents in order to readily unite with the electricity of the earth. In a number of instances the electricity has also left the lower end of the lightning-conductor, C, and passed through the foundation wall, B, into the cellar, A, and over some of its contents.

It has been asserted by some scientists that water and moist earth are poor conductors of the electricity in a lightning discharge. Their opinion is based upon the comparative amount of resistance that is offered by water and metals to a galvanic current, which is electricity of a low potential. It must, however, be borne in mind, that the electricity in a lightning discharge is of a very high potential, and can readily overcome the resistance offered by water or moist earth. The moist routes selected by lightning discharges while passing through the air, over buildings, and in the earth, and the fact that well-moist earth is not torn up thereby, fully demonstrate that water and moist earth offer an easy path for said electricity, when a suitable quantity is present.

In order to effect proper protection, the lower terminal of a lightning-conductor should be in the earth to the depth of at least ten feet, and have not less than six square feet of metal surface in contact with well-moist clay, gravel, or sandy soil.

It is principally owing to the small quantity of metal contained in the earth terminals of the lightning-conductors now erected, also the dry condition and poor conductivity of the earth and stone walls around and beneath them, that they cannot be relied upon for the safe passage of heavy lightning discharges.

No other good features that a lightning-conductor may have, can possibly make up for a small earth terminal and ground path of poor conductivity, around and beneath it.

Reliable Lightning-Conductors.

THE following metallic conductors are capable of safely conveying the electricity in a heavy lightning discharge, and when well connected with the earth, will effect proper protection.

A metal roof, iron front and cornice, stack, cupola, and any cast or rolled iron pipe or bar extending from the roof to the ground floor of a building.

A sheet-iron pipe or band, with soldered or tight-fitting joints, and made of plates not less than 12 inches long, and weighing not less than .50 of a pound per lineal foot.

		Weight per sq. foot.
Iron plate, coated with tin or other metal.	IC brand = $\frac{1}{80}$ inch in thickness	.52
	IX " = $\frac{1}{64}$ " "	.64
	IXX " = $\frac{1}{55}$ " "	.74

Rain-pipes		Weight per lin. foot
Cylindrical, 3 inches in diameter, Rectangular, $2\frac{3}{4}$ by 2 inches, Of tin or terne plate, 10 inches wide,	IC brand	.47
	IX "	.58
	IXX "	.66
Cylindrical, 4 inches in diameter, Rectangular, 4 by $2\frac{3}{4}$ inches, Of tin or terne plate, 14 inches wide,	IC "	.63
	IX "	.78
	IXX "	.90
Corrugated, 3 inches in diameter,	of No. 30 B. W. G. sheet-iron, galv.	.55
" 4 " "		.74
Gas-pipe, inside diameter, $\frac{3}{8}$ inch		.56
" " " $\frac{1}{2}$ "		.85
" " " $\frac{3}{4}$ "		1.12
" " " 1 "		1.67
Flat iron bar, $1\frac{1}{2}$ by $\frac{1}{8}$ inch		.63
" " 2 " $\frac{1}{8}$ "		.84
" " $2\frac{1}{2}$ " $\frac{1}{8}$ "		1.04
" " 3 " $\frac{1}{8}$ "		1.25
Round iron bar, $\frac{1}{2}$ inch, for air terminals		.66
" " $\frac{5}{8}$ " " "		1.03
Galvanized sheet-iron band, 6 inches wide, No. 23 B. W. G. in thickness		.60
" " " 6 " " " 20 " "		.88

						Weight per lin. foot.
Galvanized sheet-iron band,	9 inches wide,	No. 27	B. W. G.	in thickness.		.65
" " "	9 "	" " 23	"	"	..	.89
" " "	1 foot	" " 30	"	"	..	.63
" " "	1 "	" " 27	"	"	..	.88

The weight of the rain-pipes named include a well-soldered seam. The cylindrical and rectangular rain-pipes have generally been made of IC and IX tin and terne plate, fourteen and twenty inches long, and the corrugated rain-pipes of No. 30 B. W. G. sheet iron, galvanized, thirty-six inches long. If the said rain-pipes would be made of plates, IXX brand, or No. 27 B. W. G. in thickness, including the tin or zinc coating, and about thirty-six inches long, they would be more substantial, and better adapted for the passage of the electricity in a heavy lightning discharge.

Nearly every writer on lightning-conductors has asserted that copper is the proper metal for a lightning-conductor, and that a copper conductor is about six times better adapted for a lightning discharge than one of iron of the same size. Pure copper offers about six times, and the ordinary commercial copper about four times, less resistance than iron to a galvanic current, or electricity of a low potential; but a lightning discharge which is electricity of a very high potential, is able to overcome ordinary resistance very readily. Really, the difference between the conductivity of copper and iron to the electricity in a lightning discharge is so small that it practically amounts to nothing.

Iron is many thousand times a better conductor of the electricity in a lightning discharge than wood, brick, stone, and other material of poor conductivity, of which buildings are usually constructed, provided a sufficient quantity thereof is employed in a suitable form and placed in a short and direct route between the points of the discharge. Its advantages over copper are cheapness, greater resistance to mechanical injury and high temperature of fusion (2.786° Fahrenheit as compared with 1.994° for copper). It is also less tempting to the thief, who has on a number of occasions stolen part of the copper conductors erected upon buildings, thereby breaking their continuity and making the remaining portions useless.

Two dissimilar metals, like copper and iron or zinc combined, should be avoided in the construction of any part of a lightning-conductor which is exposed to constant or excessive moisture, as a chemical action caused by the moisture takes place between them — the same as in a galvanic cell or battery — causing the iron or zinc to be eaten away, and eventually nothing is left but a small quantity of copper.

Sheet-iron conductors should be coated with zinc, tin, or any other suitable metal, and painted, in order to prevent them becoming rusted. The parts of other iron conductors should be joined together by means of slip, screw, or other tight-fitting joints, and, whenever convenient, they can be soldered. Paint or an ordinary amount of rust upon the surface of a conductor does not affect its conductivity, and when rust, paint, or any other substance exists at a tight-fitting joint, the electricity in a lightning discharge can readily pass over it.

The Reliability of Metal Roofs, Sheet-Iron Bands, and the Ordinary Rain-Pipes, as Lightning-Conductors.

It has been fully demonstrated that the electricity in a heavy lightning discharge will not confine itself to the round iron rods, wire cables, spiral twisted, and other peculiar and concentrated forms of lightning-conductors heretofore employed, owing to the great expansive action of said electricity.

Proper protection can only be effected by applying broad and capacious metallic conductors to a building and in the earth, so that the electricity can be greatly diffused, and thereby disarmed of its destructive energy.

A metal roof, and tin-plate, or galvanized sheet-iron, in the form of a pipe, band or course, are really the most suitable metallic conductors by which absolute protection can be effected, as they are properly adapted for the great expansive action of the electricity in a lightning discharge.

When a lightning discharge passes through a solid rod $\frac{7}{16}$ inch in diameter, its expansive action is confined to a much smaller

scope or space than when it passes through the same quantity of metal in the form of an ordinary tinned iron plate, or a hollow cylinder like a rain-pipe. In the case of the plate or rain-pipe, the electricity of great intensity can spread out and become electricity of lesser intensity.

It has generally been supposed that a metal roof and its rain-pipes were poor conductors of the electricity in a lightning discharge, owing to the thinness of the metal employed. They are, however, much better adapted for lightning protection, if well connected with the earth, than any other ordinary metallic conductors that can be employed. A rain-pipe four inches in diameter, or a band or course made of tin or terne plate, IXX brand, fourteen inches wide, has about the same quantity of metal per lineal foot as a round iron rod $\frac{9}{16}$ inch in diameter; and if its parts are well fitted or soldered together, it is fully three times better adapted as a lightning-conductor than the best copper conductor now erected, having much more capacity for the expansive action of the electricity in a lightning discharge, and thereby able to greatly diminish its mechanical force.

That a metallic roof and its rain-pipes constitute a much better path for the electricity in lightning discharges than the metallic conductors heretofore employed, has been frequently demonstrated. On quite a number of occasions the ordinary lightning-conductors or rods erected upon buildings were struck at their air terminal or highest portions by lightning discharges; and at the points nearest to the metal roofs or rain-pipes the principal portion of the electricity left the regular conductors, and passed over to and down the metal roofs, rain-pipes, and rain-water flowing out of the lower ends to the earth, owing to the fact that the rain-pipes and the water flowing out of them furnished a better medium for the expansive action of the electricity, and an easier path to the earth than the regular lightning-conductors and the dry earth which surrounded their lower terminals. In a number of such cases the metal roofs and rain-pipes were partially melted at the points where the discharges entered and left them, and the pavement and earth beneath the outlet of the pipes were torn up. By properly connect-

ing the rain-pipes with the earth, all liability of damage to the metal roofs, rain-pipes, building, and pavement will be prevented.

The reliability of metal roofs and rain-pipes as lightning-conductors, when electrically connected with the earth, has also been mentioned by Arago, the celebrated French scientist. He states that the temple of Jerusalem, which stood from the time of Solomon until the year 588 before Christ, a period of over 424 years, was protected from lightning and never damaged. The temple was fairly exposed to the violent thunder-storms which prevailed in Palestine, and its protection therefrom is explained as follows: The roof thereof was made of cedar wood, which was covered with thick gilding. In order to prevent the birds from alighting upon and defiling the gilding upon the roof, long upright spears of steel, pointed and gilded, adorned the roof. These metallic spears connected with the gilding of the roof, and the gilding connected with the metallic rain-pipes, which terminated in the water-pools under the porch of the temple, thereby constituting, not by design, but fortuitously, a reliable combination of lightning-conductors.

A similar instance is found in the case of the cathedral at Geneva. This building, the most prominent and elevated in the city, has for about three centuries enjoyed a perfect immunity from damage by lightning, while the bell-tower of St. Gervais, situated much lower than the cathedral, has frequently been damaged. This is owing to the great central tower of the cathedral, which is built of wood, being covered from its summit with tinned iron plate, and connected at the base of the tower with the metal covering upon the roof; the latter-named covering being connected with metal rain-pipes, which communicate with an extensive system of ordinary iron drain-pipes imbedded in the earth, thereby constituting a continuous metallic path of good conductivity from the highest projection to the earth, which greatly diffuses the electricity from the clouds, and prevents damage to the building.

Quite a number of other instances can be cited, where buildings furnished with metallic coverings upon their roofs, which are connected by metal rain-pipes with ordinary iron drains imbedded

for some distance in the earth, have escaped damage from lightning discharges. The iron drain-pipes emptying into sewers in many cities cannot, however, be considered as reliable earth terminals, owing to the short distance and depth they usually extend through the earth, and the dry condition thereof during the summer season.

As tin plate and galvanized sheet-iron are cheap and possess all the requirements for effecting the easy passage and proper diffusion of a lightning discharge, there is certainly no reason why they should not be employed for protecting buildings from damage by lightning. The large amount of money that is annually squandered on the worthless lightning-conductors should be applied to furnishing buildings with metal roofs or bands beneath the roofs, and more substantial rain-pipes, properly connected with the earth.

Lightning-Conductors should not be Insulated from Buildings.

During a thunder-storm, the brick, wood, and other material about a building, become oppositely electrified by the inductive influence of the electricity in the cloud above it, although not so intensely as the metal roof, pipes, etc., thereof. In addition to furnishing a path for electrical discharges between the clouds and earth, it is also necessary for the lightning-conductors to be arranged so as to effect the restoration of the disturbed electrical equilibrium of the building, without causing any damage to the building or stunning its inmates. This can be best accomplished by placing the conductors against the chimneys, or other elevated projections, roof, and walls of the building, and not separating and insulating them therefrom by means of glass or other insulators, as has been customary.

The practice of separating lightning-conductors from buildings, etc., by glass, horn, or other insulators, is not only useless but dangerous, as the disturbed electrical equilibrium of the building is thereby prevented from being safely restored. It is a prevalent opinion that by thus insulating a lightning-conductor a discharge will be prevented from entering the building. Nothing, however,

is more ridiculous than to imagine that a lightning discharge which can break through a long distance of air and shiver into fragments the most compact bodies, would be arrested in its course by a few inches of insulating substance or a few feet of air.

The non-insulation of lightning-conductors is recommended by all eminent electricians. In a paper written by Benjamin Franklin in 1767, he suggested that "the rod may be fastened to the wall, chimney, etc., with staples of iron. The lightning will not leave the rod (a good conductor) to pass into the wall (a bad conductor) through those staples."

The late Prof. Joseph Henry, Secretary Smithsonian Institution, at Washington, D. C., says "attach rods to buildings by means of iron hooks or eyes."

Sir David Brewster, an eminent English authority, says: "The conductor should be secured immediately against the building, and not be placed at a distance from it, or pass through rings of glass or other insulators. The closer the conductor is applied to the walls, the better."

As the metallic chimney caps, metal roof, rain, gas, water, ventilating, and heating pipes, are in contact with the different parts of a building, they will, when metallically connected together and employed as lightning-conductors, as hereinafter described, enable the disturbed electrical equilibrium of the whole building to be readily restored, at the time of a lightning discharge, without causing any damage to the building or injury to its inmates.

If any of the large or long metal masses about a building are disconnected from the main metallic path, they will become separate charged conductors, which, at the time a discharge is taking place between the electricity of the air and earth, will discharge their electricity over such material and inmates of the building as are in the shortest path towards the electricity descending from the clouds, when the latter reaches or is near the top portion of the main metallic path.

A Reliable System of Lightning-Conductors.

A RELIABLE system of metallic conductors for preventing buildings from being destroyed or damaged by lightning discharges has been a long-needed want.

In Figure 3 is shown a combination and arrangement of metallic conductors, devised by the writer, by which absolute protection will be effected, when the earth around and beneath the lower terminals is of a clay, gravel, or sandy nature, and is maintained in a moist condition by the waste and rain water.

A is a metallic rain-pipe of a cylindrical, corrugated, rectangular or any other suitable form,— one which will prevent the joints from bursting during the winter season by water freezing therein being preferred. When used as lightning-conductors, rain-pipes should preferably be made of tinned or galvanized sheet-iron plates about thirty-six inches long, fourteen inches wide, and IXX brand, or No. 27 Wire Gauge in thickness. Those made of tinned iron plate twelve inches long, ten inches wide, and IC brand in thickness, will answer the purpose; but they are not as substantial and reliable as those made of longer, wider, and thicker plates.

The lengths or pieces of each rain-pipe must be tightly fitted together; and it is also advisable to solder each joint, in order to prevent any two of the lengths from separating and breaking the continuity between them.

The top of each rain-pipe must also be well connected and soldered to the tinned iron or other metal roof, B, at its gutter, *b*; and in case the building has metal troughs beneath the eaves of the metal roof, the tops of the rain-pipes must be soldered to the troughs, and a metallic connection made between the troughs and the metal roof by means of tin plates, IXX brand, fourteen inches wide, well soldered to the roof and each trough, and which should be arranged like sheet-metal band, G, in Figure 6, so that the centre of each plate will be about in line with the centre of the opening in the trough where it empties into the rain-pipe, and thereby effect direct and easy paths over the metal troughs between the metal roof and each rain-pipe.

The lower or elbow portion, *a*, of each rain-pipe should also be tightly fitted to its adjacent length; but in such sections of the country where the winter season is very cold it is not advisable to

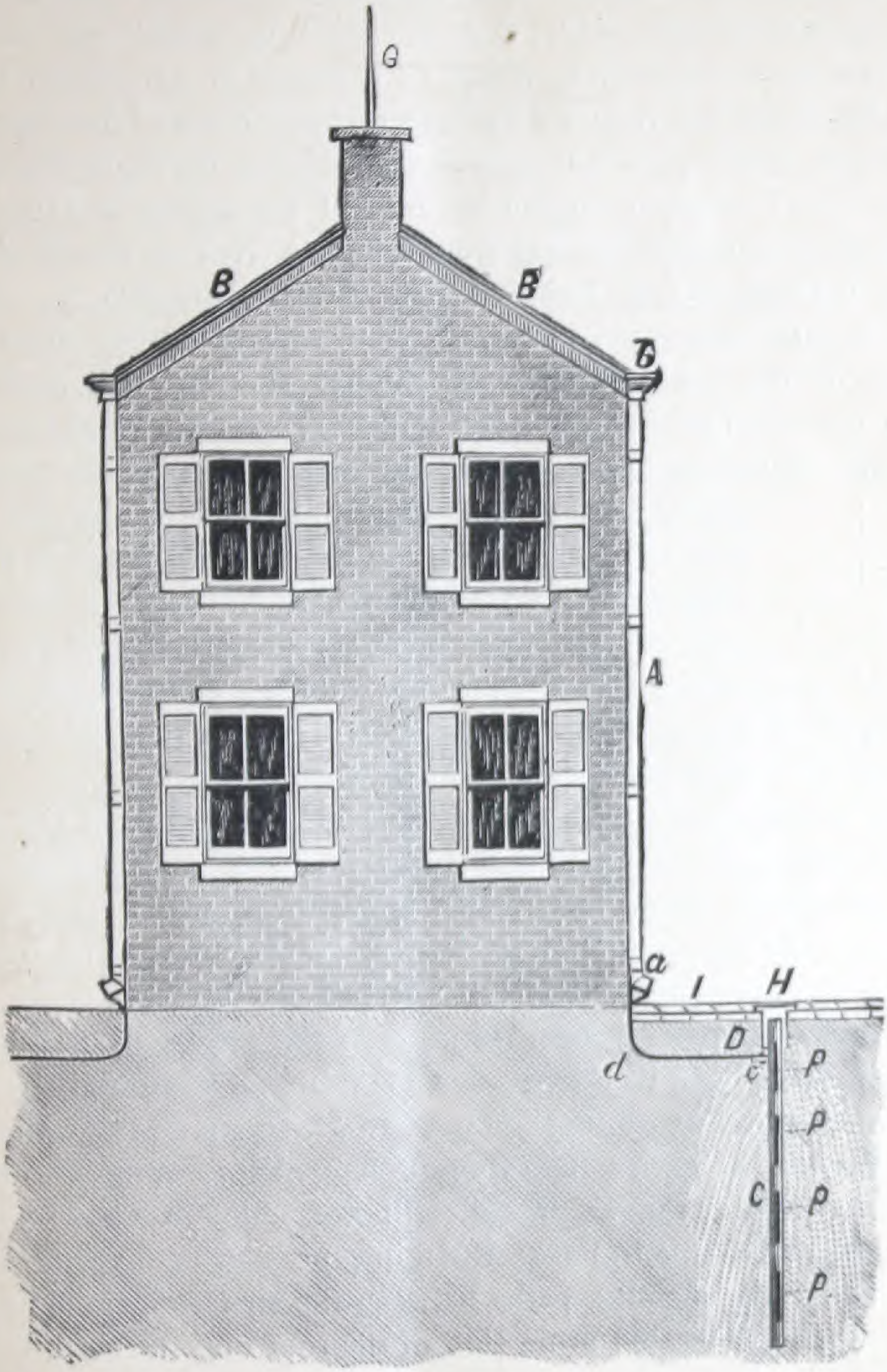

Fig 3.

solder the joint, as the pipe, A, is apt to become filled with ice during very cold weather, and it is sometimes necessary to disconnect the lower portion, *a*, in order to remove the ice therefrom.

When two buildings of different height, having metal roofs, are adjacent to each other, it is advisable to metallically connect the said roofs together by means of a tinned or galvanized sheet-iron band, not less than ten inches wide, and No. 27 Wire Gauge in thickness, which should be placed so that the routes between the air-terminal conductors upon the roof of the higher building and the nearest rain-pipe, leading from the metal roof or trough of the lower building to the earth, will be as direct as possible.

A suitable rain-pipe, connected with and extending from the gutter of the metal roof of the higher building and emptying upon the metal roof of the lower building, can be used as the connecting conductor between the said metal roofs by soldering a plate, J, of tinned or galvanized sheet-iron, not less than ten inches wide, and No. 27 Wire Gauge in thickness, or two plates, each five inches wide, to the lower part of the elbow or lower portion, K, of the said rain-pipe and the metal roof, L, of the lower building, as shown in Figure 4, and thereby effect a proper electrical connection between them.

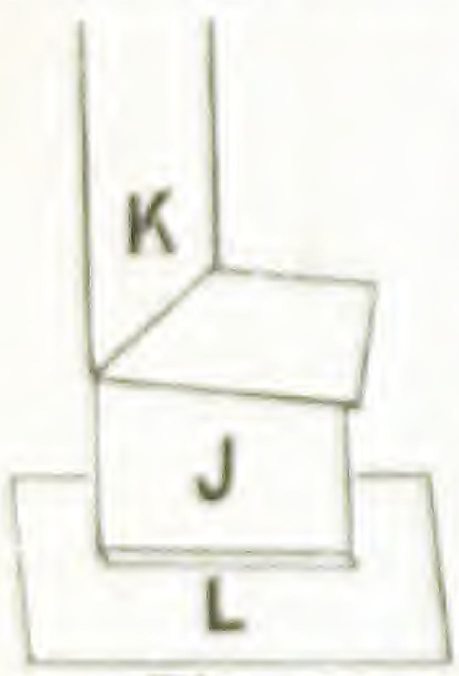

Fig. 4.

The elbow portion of a rain-pipe which extends from the eave of a building and empties upon the metal roof of a shed or portico, should be connected in a similar manner to the said metal roof, and the rain-pipe leading from the said roof is to be used as the connecting conductor with the earth.

In order to effect a proper diffusion of the electricity in a lightning discharge, and thereby protect a building, it is necessary to connect each rain-pipe leading to the earth with a good earth terminal.

As the electricity in a lightning discharge has a strong downward tendency towards the earth, and will not follow a very indirect route, it is advisable to locate the rain-pipes and their earth terminal so that the metallic paths between the air-terminal conductor upon the most elevated projection of the roof and the earth terminals, will be in as short and direct routes as can conveniently be

made; and in no case should the distance between any two rain-pipes exceed fifty feet. In every instance where a metal roof and its rain-pipes were well connected electrically with the earth, no damage was done by a lightning discharge to the building, metal roof, or its rain-pipes. On the other hand, quite a number of buildings having metal roofs and rain-pipes have been damaged and destroyed by heavy electrical discharges, and the inmates injured and killed, owing to the rain-pipes not having been connected with the earth.

When a metal roof and its rain-pipes are disconnected, or not well connected with the earth, they are, to a certain extent, like many of the worthless lightning-conductors now erected. They will receive a heavy lightning discharge, but not having proper earth terminals or connections by which the electricity can be readily diffused in the earth, the building is liable to be destroyed or damaged, and the inmates killed or injured.

The Air-Terminal Conductors.

THE chimney of a building from which heated air and smoke escape, is more apt to be struck by a lightning discharge than any other elevated projection or part of a building. This is owing to the current of heated air and smoke forming, in connection with the soot in the chimney, a line of medium conductors leading to the stove-pipe and stove, heater, or range in the building, and thereby making an easier and shorter path to the earth than other portions of the building. It is therefore necessary that a suitable metallic conductor should be employed along and above each chimney, also other elevated projections upon the roof, in order to properly protect them, and prevent the electricity from entering the building. As chimneys and other ordinary projections upon the roofs of buildings do not offer a wide scope for the expansive action of the electricity in a lightning discharge, it is not necessary to employ broad metallic conductors to protect them, but wherever convenient they should be used.

A round iron rod, G, half an inch in diameter, is well adapted as an air-terminal conductor, when arranged as shown in Figure 3.

It is substantial and not liable to be bent by the wind, which occurs with the wire cables and other forms of lightning-conductors now erected. It extends from the ridge of the metal roof, B, about four feet above the top of the chimney or other elevated projection, and is fastened thereto by iron staples. Its lower end should be well connected with a flat iron bar about 30 inches long, $1\frac{1}{2}$ inches wide, and $\frac{1}{8}$ inch thick, which should be bent like the bar, F, in Figure 7, and fitted over the ridge of the metal roof, B, and soldered thereto, and thereby establish a good electrical connection between the rod, G, and the metal roof, B, on both sides of the ridge.

A great deal of importance has been given to the manner of terminating the upper end of an air-terminal conductor. The prevalent opinion is that it should have one or more bright points, as suggested by Franklin in 1750. It is true, that when the electricity accumulated in a Leyden jar is discharged by means of a sharp point, there is not that snapping spark which occurs when a blunt end or ball is employed; but when we consider the great quantity of electricity accumulated in a thunder-cloud, and the great expansive action of a lightning discharge, it is quite evident that the electrical experiments made by Franklin with the Leyden jar, upon which the employment of points upon the upper end of a lightning-conductor is based, cannot be considered as legitimate illustrations for determining the necessary requirements for effecting protection from atmospheric electricity.

To improve its appearance, the upper end of an air-terminal rod can be pointed, but it need not be tipped with platinum, copper, or any other metal.

The electricity in a lightning discharge frequently passes through 5000 feet of air, which is the poorest conductor, to reach the earth; and it is therefore absurd to suppose that a small thickness of rust that may be formed upon the upper end or any other part of a lightning-conductor, will prevent the electricity from the clouds readily passing through it and over the conductor to the earth.

A chimney can also be properly protected by means of an ordinary galvanized sheet or cast iron cap thereon, which must be connected with the metal roof by a suitable flat iron bar, or prefer-

ably by a band of tinned or galvanized sheet-iron not less than nine inches wide, and No. 23 Wire Gauge in thickness; and when the chimney is in line with the ridge of the roof, the centre of the connecting band should be in line with the ridge of the metal roof.

When a chimney is located below the ridge or near the eave of the roof, it is advisable to employ a metal cap thereon, and connect it with the metal roof, in addition to employing the air-terminal rod, G, extending above the ridge. Metallic ventilators, cornices, iron railings, and all other metal masses upon the roof of a building or a projection thereof, must also be connected with the metal roof by a similar sheet-iron band, and thereby serve as air-terminal conductors, for which purpose it has been fully demonstrated they are much better adapted than all the polished points that can be employed. A platinum, copper, or other metal point is invariably melted by the electricity in a lightning discharge, while there is but little fusion of metal when a large metal mass is struck by a lightning discharge, and particularly when it is well connected with the earth, for the reason that a wide scope is given to the electricity, and its intensity is thereby greatly diminished.

A flagstaff upon the roof of a building should have a galvanized iron wire, about No. 6 Wire Gauge in thickness, attached thereto by iron staples, or be set in a groove in the pole, in order to prevent it being split into fragments by a lightning discharge. The upper end of the wire should extend about six inches above the top of the pole, and the lower end be soldered to the metal roof or other suitable conductor upon the roof.

It is advisable to so place the air-terminal conductors at such points along the ridge of the roof of a building as to be in as short lines as possible with the rain-pipes leading from the eaves of the roof to the earth; and where the distance between the rain-pipes or two chimneys, or other projections upon the roof of the building, exceeds forty feet, it is prudent to erect an intermediate air-terminal conductor extending above the ridge, and connect it with the metal roof or other suitable conductors leading in short lines with the nearest rain-pipes, and wherever convenient the distance between the air terminals should not exceed thirty feet.

An Improved and Reliable Earth Terminal.

Scientific journals and writers on lightning-conductors have generally recommended that they be terminated in well-moist earth, but they have neglected to state that the surface earth adjacent to a building is, as a rule, kept rather dry, and particularly during the summer season.

Well-moist earth of a suitable area can only be found, during the summer season, in the immediate vicinity of springs, creeks, streams of water, and the subterranean water-bed. The depth of the water-bed below the surface of the earth can be ascertained by measuring the distance to the level of the water in the wells in the neighborhood.

Charcoal, coke, scraps of iron, and metallic ores have also been recommended and placed around the lower terminals of lightning-conductors, by which the area of good conducting material is increased in the earth; but owing to the small quantity of said material that can conveniently be used, and the dry condition of the earth around and beneath the charcoal, etc., a proper diffusion of the electricity in lightning discharges cannot be effected by the employment of said material.

The writer has given the subject of earth terminals for lightning-conductors considerable attention, and has overcome the difficulty that has heretofore been experienced in effecting the proper diffusion and easy passage of the electricity in lightning discharges in the earth, by employing the waste and rain water in connection with the improved earth terminal, C, as shown in Figure 3.

The improved earth terminal consists of a pipe not less than ten feet long, two inches inside diameter, and about one-quarter inch thick, made preferably of rolled iron in a single length, or two or more lengths, each about five feet long, with the usual opening at each end, and perforations or openings, P, along its length. The said perforations can be ten inches long and one-quarter inch wide, and be placed at intervals of about ten inches from each other, preferably in two lines opposite each other.

A plate of rolled iron can be employed in the form of a pipe,

with the longitudinal ends separated about a quarter of an inch, so that water can escape into the earth along its entire length, and also allow the pipe to expand when ice is formed therein. The pipe, C, can be round, square, triangular, or any other suitable form; and instead of employing a solid pipe with perforations, curved, flat, or angle bars of iron can be employed and be attached at both ends, also the centre, to suitable metallic devices, so there will be suitable spaces or openings between the bars, through which the water can pass and moisten the surrounding earth, and answer the same purpose as a solid perforated pipe.

The pipe, C, can be driven into clay, sand, and gravel soil in the same manner as the pipe of a driven well is placed in the earth. A metal shoe with sharp edge can be used at its lower end instead of the pointed device used with the driven well pipe, and the earth removed from the interior of the pipe by means of a common screw auger of suitable diameter, which can also be used for testing the ground before driving down the pipe, and thereby avoid striking large stones or solid rock.

Pipe C should be placed so that the waste water from a hydrant or pump in the vicinity of the building, and the rain-water from the pipe, A, flowing along the gutter or drain, I, will readily enter it through its top opening, and passing through its lower and side openings, cause a suitable area of earth around and beneath it to become and remain moist during the whole year, and thereby effect an easy electrical path between the lower end of the pipe, C, and the subterranean water-bed.

Wherever convenient, the pipe, C, should be located not less than eight feet from the foundation wall of the building, so as to allow a suitable area of earth to be moistened, and prevent the said wall becoming saturated with moisture. In cities and towns it can be placed near the curb line or in the street gutter, when employed in connection with the rain-pipe, or other lightning-conductor, along the front part of the building, and where the earth terminal must be placed within eight feet of the foundation wall of a building in order to be in line with the flowing waste and rain water along a gutter or drain, it is necessary to employ a solid pipe with-

out perforations between the surface of the earth and a point about two feet below the surface of the cellar of the building, and a perforated pipe not less than six feet long below the solid pipe, and thereby maintain a suitable area of moist earth below the surface of the cellar and without saturating the foundation wall or walls of the building with moisture.

Pipe C should, preferably, be set in the earth so that its upper end will be about six inches below the surface of the earth, so as not to be exposed to the rays of the sun and become greatly heated during the summer season, and thereby prevent the moist earth around its upper end being soon dried up. A suitable pipe, H, about four inches inside diameter and eight inches in length, can be placed around the upper end of pipe, C, but not in contact with it. Its upper end should be nearly flush with the gutter or drain, I, or the surface of the earth, and contain a perforated screen, which will allow the water to flow readily into pipe C and around its top, but prevent the passage of trash therein, with which it might otherwise become filled.

The top of pipe C can be set nearly flush with the gutter, I, and be covered with a suitable screen, and thereby dispense with the pipe, H, where the pipe, C, is not exposed to the sun or is required to be placed near the foundation wall of a building.

In large cities the rain-pipes upon buildings generally connect with and empty into iron drain-pipes leading into sewers, which cannot be considered as reliable earth terminals, owing to the short depth they usually extend through the earth and its dry condition during the summer season. In such cases it will be necessary to place a perforated pipe not less than six feet long in the earth, with its top about two feet beneath the surface of a cellar, vault, or any other suitable place convenient to the drain-pipe, and be supplied with water therefrom by means of an iron pipe about two inches outside diameter, which must be properly connected with the drain-pipe, and tightly fit into the top portion of the perforated pipe, so that the water will readily flow from the drain-pipe into the perforated pipe, and at the same time prevent the surface portion of the cellar or vault becoming saturated with

water, as it is not desirable to have it in a very damp or moist condition.

During the beginning of a thunder-storm, the water from rain-pipe A, flowing along the gutter I, will soon fill the pipes C and H, and flow in a body over them, and establish an electrical connection between the top of pipe, C, and the moist surface earth, which, together with the moist earth around and beneath the pipe C, will greatly diffuse the principal portion of a lightning discharge, that portion of the discharge passing down the walls of the building to the earth being harmless. Solid rock greatly impedes the electricity of a lightning discharge in its passage from the surface earth to the subterranean water-bed, and to drill a hole in the rock so that an earth terminal can reach the water-bed is rather expensive. The liability of damage to a building erected over a stratum of solid rock can be greatly lessened by providing it with a metal roof and connecting its rain-pipes with earth terminals of suitable forms, each having not less than forty square feet of surface, which should be placed vertically in the earth, as deep as possible, and with the top portions contacting with the rain-water flowing along the gutters.

Several other devices and methods have been tried for moistening the earth around a metallic terminal, but they have been found to be unreliable, owing to the small area and short depth of earth made moist.

The perforated iron pipe, arranged as described, is the only unobjectionable and reliable method by which the waste and rain water can be made use of for maintaining a suitable area of moist earth, and effecting the proper diffusion of the electricity in lightning discharges in the earth.

It enables the rain-water during a thunder-storm to spread out over a large area of earth and to a considerable depth *in a short space of time*, which is a very important feature. It also enables the waste water to enter the earth at a depth where it is not so compact as at or near the surface, and where it is not dried up by the heat of the sun, thereby constantly maintaining a line of moist earth extending towards the subterranean water-bed.

It is the only arrangement by which the rain-water flowing along a gutter and over the surface earth, during a storm, can conveniently be used to diffuse a considerable portion of the electricity in a lightning discharge.

Connecting Conductors between the Rain-pipes and Earth Terminals.

A METALLIC connection must be made between the rain-pipe, A, and the perforated pipe, C, by means of a suitable metallic conductor, D, which can consist of a flat iron bar not less than two inches wide and one-eighth inch thick, and be bent at *d*, as shown. The vertical portion should be placed with its wide part parallel with the wall of the building, and, if necessary, be fastened thereto by a suitable staple or other device, and the horizontal portion should be imbedded in the earth to the depth of about ten inches.

The upper portion of bar, D, should be placed behind the rain-pipe, A, and extend about eight inches above the top of the elbow portion, *a*.

To the length of rain-pipe, A, above the elbow portion, *a*, a suitable galvanized iron socket or slip joint device, E, about six inches in length, is connected, as shown in Figure 5, preferably by soldering. Into the opening thereof, the upper end of flat bar, D, is inserted about five inches and fits snugly therein, so as to form a good electrical connection between them. To the lower side of the elbow portion, *a*, of the rain-pipe, A, the curved conductor, F, is soldered, which is connected to flat bar, D, by one or more screws or other suitable devices. The object of the two connecting devices, E and F, is to effect an easy passage of electricity between the rain-pipe and the connecting conductor, D; and should it be necessary to remove the lower or elbow portion, *a*, the continuity between the rain-pipe, A, and the conductor, D, will be maintained by device E.

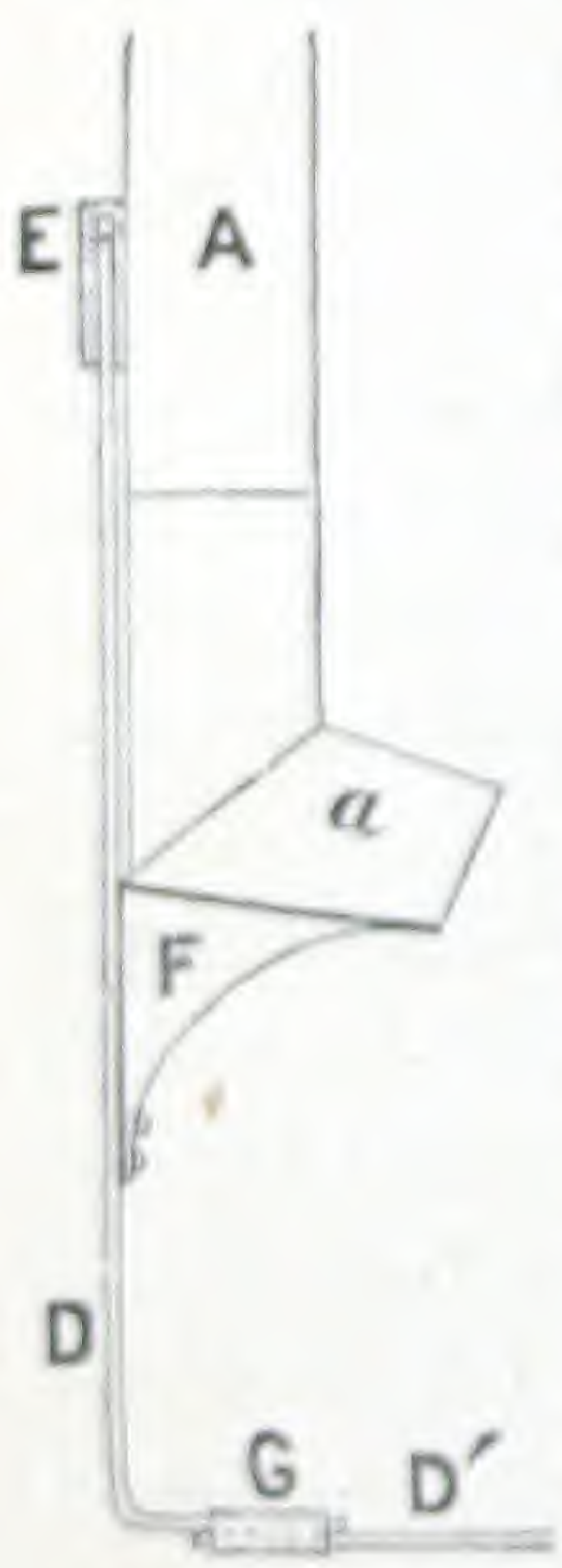

Fig. 5.

To the side of the earth-terminal pipe, C, an iron projection or arm, *c*, about six inches long, one-quarter inch thick, and the same width as bar D, should be attached, to which the end of the horizontal portion of bar, D, must be well joined by means of a bolt and nut, sleeve, or other suitable device.

Instead of employing the connecting bar D in one length, two bars, D and D′, can be used, the ends of which should be well joined together by a sleeve, G; and instead of the flat bar D′, sleeve G, and arm *c*, any other suitable connecting conductors can be employed. In cities and towns the conductor D′ can be driven into the earth from the cellar to the gutter, and thereby avoid tearing up a pavement or gutter.

Should the building have gas and water pipes, the bar, D, or any other convenient connecting conductor attached to the nearest rain-pipe, must be connected with the said pipes near the foundation wall of the building, either inside or outside the cellar, by means of a wire cable or other flexible conductor, having not less than .40 of a pound per lineal foot, thereby aiding in the diffusion of the electricity of a lightning discharge in the earth, and also safely restoring the disturbed electrical equilibrium of the building, and preventing lateral discharges between the said rain-pipe and the gas and water pipes.

Some of the gas corporations have objected to connecting lightning-conductors with the pipes leading to the gas mains, and making use of them as earth terminals. They should, however, bear in mind that the electricity of the clouds and earth have, by their inductive influence, an affinity for the gas mains; and if the nearest rain-pipe or other lightning-conductor is not connected with the pipe leading to the gas main, near where it passes through the foundation wall of a building, a lightning discharge itself is nevertheless disposed, and may be able, to reach the gas main by passing through the wall to the nearest gas-pipe inside the building, melting the lead joints of the meter and setting the escaping gas on fire.

Gas and water mains are generally imbedded in the earth to the depth of about four and a half feet, and during the summer season the earth around them is kept in a rather dry condition,

which has caused lightning discharges upon a number of occasions to melt the lead packing at the joints of the street mains, and caused the gas and water to escape. The perforated iron pipe, C, in connection with the moist earth and flowing rain-water, during a storm, is better able to diminish the intensity of a lightning discharge than the gas and water pipes and mains in the vicinity of a building; and when a connection is made between the perforated pipe, C, or rather its connecting conductor, D, and the gas and water pipes, as recommended, the lead packing at the joints of the gas and water mains will be prevented from being melted by a heavy lightning discharge.

Protection of Wooden, Slate, Gravel and Mansard Roofs, Steeples, etc.

In the application of lightning-conductors to wooden, slate, gravel, and other roofs, it has been customary to place them upon the outside, along the ridges and down one or both ends or sides of the buildings, and also along other parts of the roofs, so that the routes between the air-terminals and the vertical portions of the conductors leading from the eaves or ends of the buildings to the earth are long and indirect, and thereby jeopardize the roofs, as the electricity in a lightning discharge will not follow a metallic conductor or path when it is in a long and indirect route. Many of the lightning-conductors now erected are in very indirect routes upon the roofs of buildings, as shown in Figure 1, and consequently will not effect proper protection.

The application of metallic conductors upon the outside of wooden, slate, gravel, and Mansard roofs, steeples, and other elevated projections, and particularly in short and direct lines is objectionable, as the roofs, etc., are disfigured by the conductors, and in attaching their fastenings to the roofs, the slate is broken and shingles or wood-work split, so as to allow the water to enter the interior of the buildings during a storm or from melting snow upon the roofs.

Lightning-conductors placed upon the outside of slate roofs are also apt to be torn from their fastenings and carried to the ground

by the large quantity of snow which generally accumulates and presses against them during the winter season.

In order to effectually prevent wooden, slate, and other roofs, steeples, towers, observatories, skylights, and other elevated projections above the roofs, from being damaged by lightning discharges, and also disfigured and damaged in applying lightning-conductors thereto, it is necessary to employ bands of tin plate or galvanized sheet-iron, having the same quantity of metal per lineal foot as the rain-pipes extending from the eaves of the roofs to the earth, and place them in as short and direct lines as possible beneath the slate covering or wooden laths or rafters of the roof, etc., between the air-terminal conductors and the said rain-pipes. The said bands and rain-pipes should, preferably, be made of tinned or galvanized iron plates, about 36 inches long, 14 inches wide, IXX brand or No. 27 Wire Gauge in thickness. In Figure

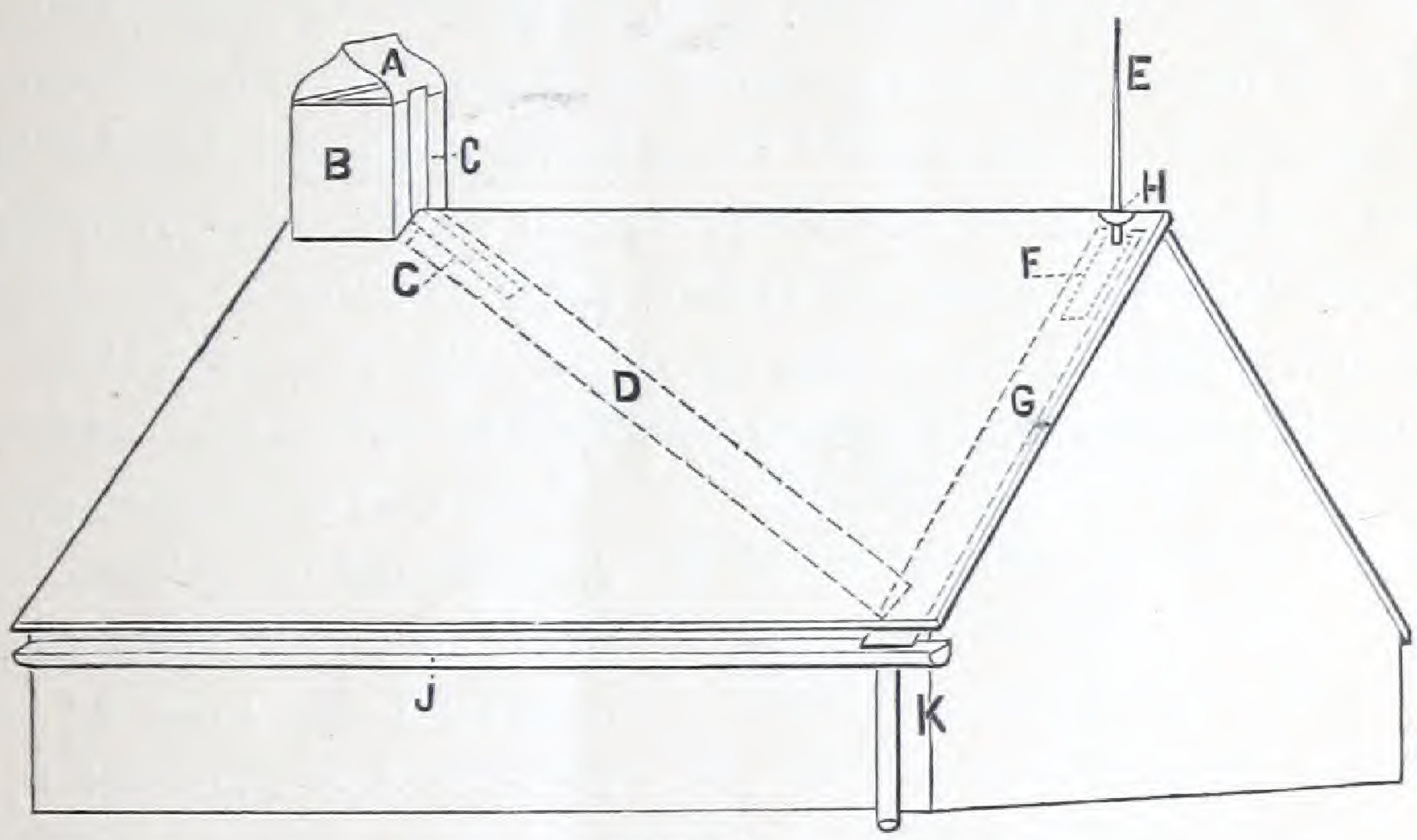

Fig. 6.

6 is shown an arrangement of metallic conductors upon one side of a slate, wooden, or gravel roof of a building, not exceeding thirty feet in length or width, by which proper protection will be effected. A is a cast or galvanized sheet-iron cap or ventilator upon the top of chimney, B, at one end of the roof, and serves as an air-terminal conductor. E is a round iron rod about five feet long, and serves as the air-terminal conductor at the other end of the

roof. J is an ordinary metallic trough beneath the eave of the roof, and to which the metallic rain-pipe, K, which must not be less than three inches in diameter, is well soldered.

D and G are sheet-metal bands, the plates of which are of the same width and thickness as those employed in the rain-pipe, K, and are placed beneath the wooden laths or rafters of the roof, in as short and direct lines as possible, with the centre of the chimney-cap, A, rod, E, and rain-pipe, K, as shown, so as to effect an easy passage of electricity between them. Band, D, is soldered to band, G, near the eave of the roof as shown, and band, G, to the metallic trough, J. Instead of connecting the lower end of band, G, with trough, J, it can be neatly bent around rain-pipe, K, for about six inches and be well soldered thereto, and thereby effect an easy passage between the said band and every part of rain-pipe, K. Chimney-cap or ventilator, A, is connected with band, D, by a tinned or galvanized sheet-iron band, C, nine inches wide, and about No. 23 Wire Gauge in thickness, or band, D, can be extended and connected to cap, A, and thereby dispense with band, C.

The arrangement of the lower end of air-terminal rod, E, and its connection with band, G, is fully shown in Figure 7. It passes through a suitable hole in the centre of rafter, L, or a ridge pole or suitable piece of wood placed between two rafters, and is screwed into or well connected by a nut *e*, to tinned or galvanized flat iron bar, F, which is not less than 24 inches long, $1\frac{1}{2}$ inches wide, and $\frac{1}{8}$ inch thick, and bent in the centre as shown, and fastened to rafters, L and and L′, with nails, screws or staples, thereby maintaining rod, E, in a proper vertical position without requiring a standard or upright above the roof to support it, as is the case with the spiral-twisted,

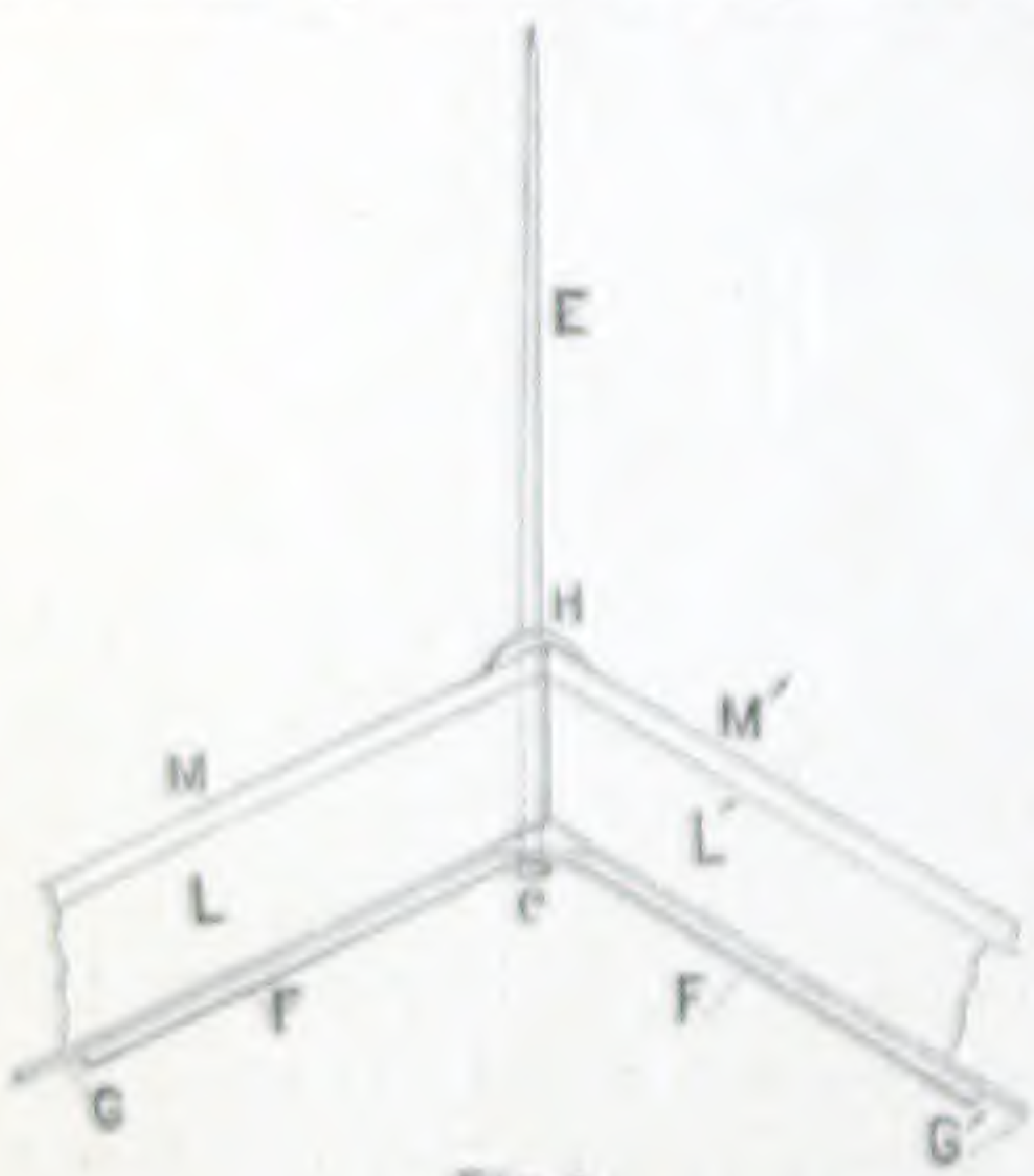

Fig. 7.

wire cables and other forms of air-terminal conductors now erected. The sheet-iron band, G, is placed between bar, F, and rafter, L, and by soldering it to the said bar, a good electrical connection will be maintained between them. In order to prevent the water flowing down the rod, E, from entering the interior of the roof during a storm, it is necessary to fit a tin plate, H, about a foot square and with a hole in its centre, around the said rod and be soldered thereto, above the slate covering or wooden sheathing M, M′, of the roof.

The sheet-metal band, G′, connects bar, F, with the metallic trough, or rain-pipe, on the other side of the building, and a sheet-metal band, similar to band, D, extends from the chimney conductor, C, or a branch thereof, to near the eave of the other side of the roof and is connected to band, G′, thereby maintaining two metallic paths from both chimney-cap, A, and rod, E, to the rain-pipes on both sides of the building.

Should the building exceed thirty feet in length or width, it will be necessary to erect one or more intermediate air-terminal conductors along the ridge of the roof, and connect them by means of suitable sheet-metal bands with the nearest rain-pipes on both sides of the building.

In the case of a slate roof, the sheet-metal bands on both sides of the roof can be placed between the slate covering and felt or wooden sheathing, and be soldered to the metallic gutter or trough along the eaves, and the conductors connected with chimney-cap, A, and rod, E. A flat iron bar, similar to bar, F, in Figure 7, should then be connected to rod, E, above the roof, and placed so that its top is flush with the top of the wooden sheathing M, M′, and the bands G and G′ placed beneath the said bar and soldered thereto.

In the case of a Mansard roof, the rain-pipes, or other sheet-metal conductors employed along the angle beads or corners, also the metal valleys between two side roofs and the metal flushings between the roofs of the dormer windows and the side roofs, can be used as the connecting conductors, or parts thereof, between the metal covering upon the deck roof and the metallic gutters above

the house cornices, provided they are in direct lines with the rain-pipes leading from the cornices to the earth, and the plates thereof are not less than ten inches wide; and where they are not in direct lines with the said rain-pipes, it will be necessary to employ suitable sheet-metal bands beneath the slate covering or wooden sheathing between the deck roof and the cornice gutters.

A high steeple upon a church or other building, should have a suitable metallic ornament at its top, which can serve as an air-terminal conductor, and answer the purpose much better than a pointed rod. A substantial iron rod, not less than an inch in diameter, should be well connected to the said ornament, and extend not less than ten feet into the interior of the steeple, and be well secured in order to hold the ornament in its position. To the lower end of said rod, a flat iron bar, like bar, F, in Figure 7, should be well connected at its centre, with the ends thereof bent downward, to which two metallic bands, preferably about 14 inches wide and No. 27 Wire Gauge in thickness, should be soldered thereto for about twelve inches. They should extend along the inner sides of the steeple, and be connected with the metal roof of the building at or near the base of the steeple, or, in case of a wooden or slate roof, the bands should be extended in line with the nearest rain-pipes on each side of the building, and be soldered to the metallic gutters or troughs at the eaves of the roof.

It is also advisable to place suitable metallic ornaments, or other conductors, around the steeple at intervals of about every twenty feet, between its top and base, and connect them with the vertical connecting bands upon the interior of the steeple, and thereby intercept any lightning discharge which might take place in line with the centre or any other portion of the steeple beneath its top, and carry it safely to the earth.

Some years ago, Ganot, a French scientist, reported to the French Academy of Science that a lightning-conductor, or its air-terminal portion, would protect a circular space the radius of which is equal to twice its height above the ground or above the roof of a building. This rule cannot always be relied upon, for the reason that a discharge is sometimes deflected from the path that it would

ordinarily take in line with the highest projecting point of a building by the rain, when it is driven in a certain direction by the wind, also by other circumstances. Lightning discharges have been conveyed by the falling rain in line with the bases of steeples and roofs of churches, instead of in line with the tops of the steeples. It is therefore advisable to employ intermediate air-terminal conductors along a steeple, and also at intervals of about twenty-five feet along the ridge of the roof of a church. Instead of employing iron rods, suitable metal ornaments about two feet high can be employed as the air-terminal conductors along the ridges of the roofs of churches and other buildings.

A suitable air-terminal conductor should be placed upon the top of an observatory or tower, and a suitable number of air-terminal conductors upon the top of a long skylight, at intervals of about twenty-five feet, and be connected with the main metal roofs, or the metallic gutters or troughs at the eaves of the roofs, by two suitable sheet-metal bands extending from each air-terminal conductor, and placed in direct lines with the nearest rain-pipes on both sides of the building.

The connecting sheet-metal bands employed between the air-terminal conductors or metal coverings upon Mansard and other roofs, and the rain-pipes leading from the eaves of buildings to the earth, should be fastened to the wood-work upon the interior of the roofs, steeples, observatories, etc., by means of nails, and need not be insulated therefrom.

If the said rain-pipes are well connected with the earth, there is no liability whatever of the wood-work, or other material about a roof, steeple, etc., being set on fire or damaged, or any person beneath the roof or inside a steeple being injured by the electricity in a lightning discharge while passing over the said metal bands.

Employment of Gas, Water, and other inside Pipes, etc., as Additional Lightning-Conductors.

During a thunder-storm, the gas, water, heating, and ventilating pipes, and other vertical metallic conductors upon the inside of a

building which extend to or near the roof thereof, become highly electrified by the inductive influence of the electricity in the cloud above, and are apt to be selected as part of the path for the passage of the electricity in a heavy lightning discharge, the expansive action thereof being sometimes so great as to cause it to fork into a number of branches as it approaches or reaches the roof of the building.

In their normal state, the said pipes and inside metallic conductors are, to a certain extent, a source of danger, during a storm, to a building and its inmates; but by properly connecting them with the metallic roof or air-terminal conductors upon the roof, or with the connecting bands between the air-terminal conductors and the rain-pipes, and also connecting them together in the cellar, and with a perforated iron pipe placed upon the outside of the building, by means of wire cables or other flexible conductors, having not less than .40 of a pound per lineal foot, they become the means for effecting the proper protection of the building, as they will greatly diminish the intensity of a lightning discharge and safely restore the disturbed electrical equilibrium of the building.

The larger the number of vertical metallic paths or conductors employed from the roof of a building to the earth, also earth terminals, the more readily will the intensity of a lightning discharge be diminished, and the greater will be the protection to the building and its inmates. Should the continuity of the rain-pipes or other metallic conductors upon the outside of the building become broken by accident or otherwise, the inside pipes or other metallic conductors will be able to properly protect the building.

A good electrical connection is always maintained at the joints of gas-pipes, for the electricity in a lightning discharge, by the iron screw threads thereof contacting with each other. If the gas-pipe which leads from the meter to the street main is connected with a perforated iron pipe, as recommended, and the iron pipes leading to and from the meter are connected together by means of a sheet-metal band, six inches wide, and No. 20 Wire

Gauge in thickness, or any other suitable conductor, so as to shunt the meter, there is no danger of great heat being generated at any joints of the meter, house pipes or street mains, and the melting of the lead at the joints and escape of gas will be prevented.

A building over one hundred feet square cannot be properly protected unless, in addition to the rain-pipes or other conductors and earth terminals upon the outside thereof, a suitable number of conductors are employed through the interior, at intervals of not less than fifty feet, and are well connected with suitable earth terminals placed not less than ten feet deep in the earth in the basement or ground floor of the building, so that as short and direct paths as possible will be provided to the earth for lightning discharges taking place in line with the central portions of the roof.

The employment of lightning-conductors through the interior of a building has been recommended by the eminent electrician Faraday, and others, in order to secure direct and easy paths to the earth for a lightning discharge. That uninsulated lightning-conductors, provided with good earth terminals or connections, can be safely employed through the interior of buildings, is evident, when we reflect that they have been safely employed during the past fifty-five years through the interior of the hulls of ships.

Lightning discharges have frequently struck the telegraph wires in the vicinity of telegraph offices, and where the office wires were provided with a good lightning protector, well connected with the earth, the electricity has passed through the offices without causing any damage to the telegraph instruments or injury to the operators.

That large metallic conductors well connected with the earth will disarm the electricity in a lightning discharge of its destructive energy, and prevent injury to persons, even when in close proximity thereto, was fully demonstrated on the evening of the 12th of April, 1877, when the Carysfort Reef lighthouse, near Key Largo, Florida, was struck seventeen times within thirty minutes by heavy lightning discharges, the thunder thereof being of the most terrific character. This lighthouse is built in the water, on a

submerged reef, and consists of a framing of stout iron pillars or piles, each about one hundred feet in length, arranged in the form of an octagon, with one pillar in the centre, interlaced at various points with smaller iron rods. At about forty feet above the water is the keeper's apartment, the roof and sides of which are of iron plate, while the floor is of wood.

During the storm several men were in the lighthouse, in close proximity to the metallic conductors surrounding them, over which the electricity passed to the water, but none were injured.

Protection of Barns, etc.

BARNS, when filled with new hay or grain, especially when it is not properly cured or dried, also buildings in which ice or other material is largely stored, are particularly liable to be struck and destroyed by lightning discharges, even when provided with the ordinary lightning-conductors, owing to the great affinity which atmospheric electricity has for large masses of hay, etc.

It is claimed that grass, when growing in the field, is covered with many minute organisms or germs, which, in the course of their growth, consume oxygen, and give off carbonic acid in great quantities, and derive their nutriment from substances of vegetable origin. When hay is not properly dried, these germs are not killed, but continue to grow, and in throwing off millions of offshoots they prey upon the grass, drink the water, and breathe the oxygen, which, however closely packed the hay may be, penetrates to the innermost recesses of the mow or stack. In doing all this, carbonic acid is produced, which, uniting with the oxygen, causes a great heat to be produced. When the heat produced by the germs has no means of escape, a temperature is reached at which the woody fibre of the hay and oxygen can combine, and ignition takes place.

The heated hay offers a much wider scope and better medium for the great expansive action of the electricity in a lightning discharge than the ordinary lightning-conductor or conductors heretofore applied to barns. The result has been that many large barns,

with their valuable contents, have been destroyed by the electricity leaving the ordinary conductors for the hay, and will continue to be destroyed until broad metallic conductors are employed, which will offer a better scope and easier path to the earth for the electricity in lightning discharges than the path offered by the hay, or other material contained in the building. A metal roof, with suitable air-terminal conductors attached thereto, and connected with at least four perforated iron pipes placed in the earth at or near each corner of the building, by means of rain-pipes four inches in diameter, will effectually protect a barn, ice-house, or other structure used for storage purposes.

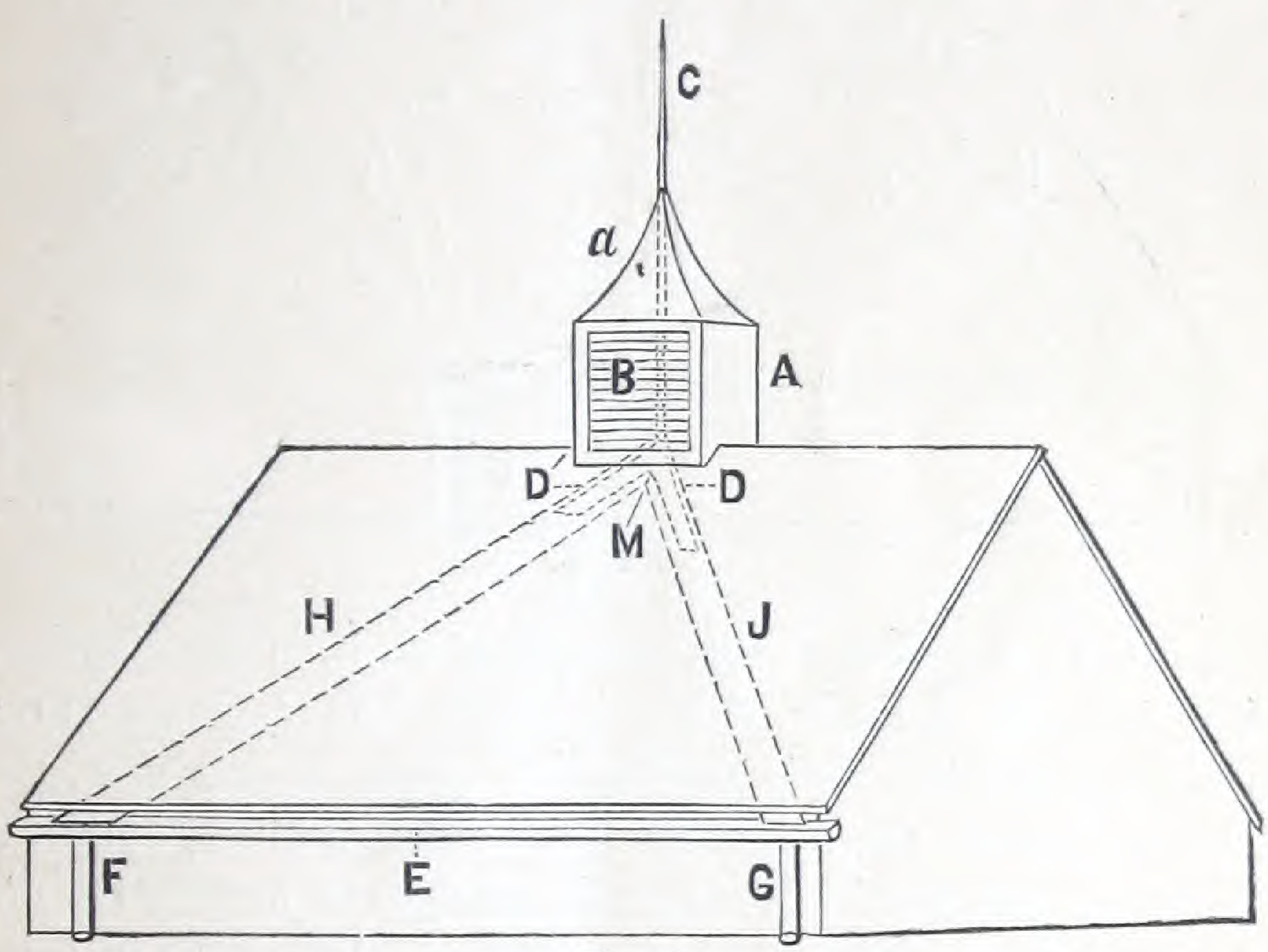

Fig. 8.

A barn having a wooden or slate roof thereon, and not exceeding thirty feet in length, can be protected by employing the conductors shown in Figure 8, and one over thirty, and not exceeding forty-five feet in length, by employing the conductors shown in Figure 9 — the sheet-metal conductors being applied to both sides of the roof, and their connecting rain-pipes connected with perforated iron pipes, not less than ten feet long, placed vertically in the earth.

A, Figure 8, and A A′, Figure 9, are wooden ventilators, not less than one foot square and three feet high, having openings, B and B B′, upon at least two sides, through which the heat generated by the hay can escape from the barn. The centres of the two ventilators in Figure 9 should each be about ten feet from the nearest gable end of the roof.

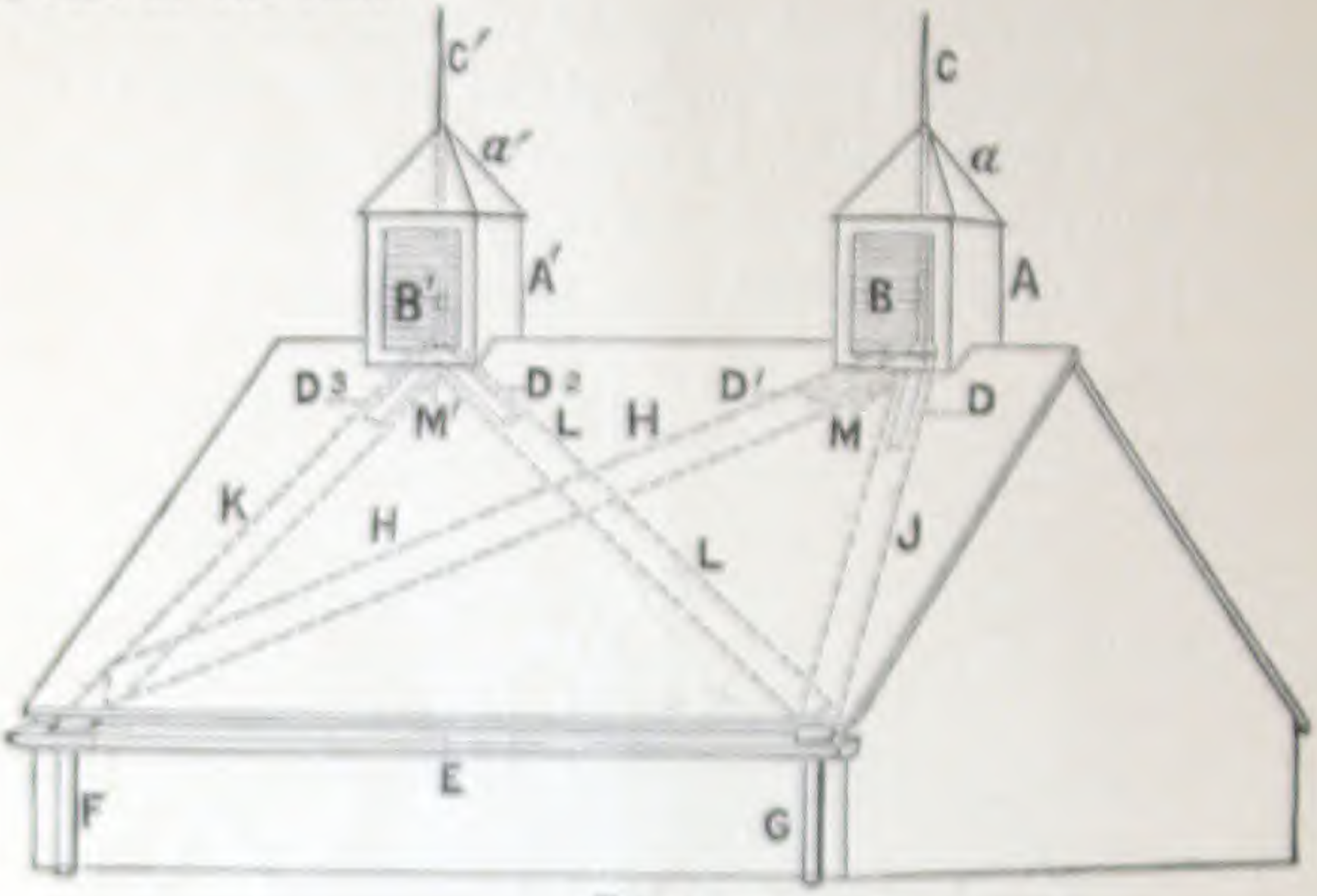

Fig. 9.

C and C C′ are round iron rods, half an inch in diameter, extending into the interior of the ventilators as shown, and not less than three feet above the tops of the roofs, *a* and *a a′*, thereof. The lower ends of the said rods pass through holes, M M′, in the centre of two flat iron bars, D D^1 and D^2 D^3, and are firmly held by a nut arranged like nut *e* in Figure 7. The said bars, which are about one and one-half inches wide, one-eighth inch thick, and of suitable length, should be bent like bar F, in Figure 7, and arranged at angles to each other, as shown in Figure 10. The ends of said bars are fastened to the rafters of the wooden or slate roof by nails or other suitable devices, and in the case of a metal roof, they are placed upon it and soldered thereto. Where there are no ventilators, the rods, C and C C′, and bars, D D^1 and D^2 D^3, must be applied to the ridges of the roofs as shown in Figure 7.

Fig. 10.

The sheet-metal bands, H, J, K, and L, are placed beneath the wooden laths or rafters, or slate covering of the roofs, and are made of tinned or galvanized iron plates fourteen inches wide, and IXX brand, or No. 27 Wire Gauge in thickness, and contact with the ends of bars D D^1 and D^2 D^3 for about twelve inches, and are soldered thereto. The lower ends of metal bands H, J, in Figure 8, and of bands J, K, in Figure 9, are soldered to metal trough E, in line with metal rain-pipes F and G. The lower ends of metal bands H, L, in Figure 9, are soldered to the bands J, K, near the eave of the roof, as shown.

A lightning discharge taking place in line with either of the air terminal rods or conductors, shown in Figures 8 and 9, will flow from the lower end thereof to the earth by four metallic paths — two on each side of the building — and be greatly diffused and weakened, and thereby prevent the ignition of the hay and other material. By connecting the lower ends of air-terminal rods C and C′, in Figure 9, together by a suitable metallic conductor, two additional but not as direct paths will be provided across the roof of the building.

Barns over forty-five feet in length should have air terminals along the ridge at intervals of about twenty feet, and rain-pipes and earth terminals along both sides of the building at intervals of about thirty feet.

As a lightning discharge has also a great affinity for a large assemblage and groups of persons, horses, and cattle, it is advisable to apply the same system of metallic conductors to churches, school-houses, places of amusement, and stables as is applied to barns, ice-houses, etc., in order to properly protect the inmates. The serious calamity which occurred during service on the 27th of May, 1877, at the Catholic church in Wieschen Posen, a Polish province of Prussia, by which six persons were killed and about seventy seriously injured, owing to the expansive action of a lightning discharge, as well as many other similar disasters, could have been prevented, had the buildings been provided with a proper system of metallic conductors.

General Information on Lightning Protection.

GENERAL information in reference to lightning protection can be found in the treatise on the subject issued by the writer in April, 1877.

It not only treats upon the protection of buildings, but also of ships, oil-tanks, steam-boilers, wooden bridges, telegraph poles, etc.

It explains the principal technical terms used in the electrical science, and the properties of the different kinds of electricity, and also gives the formation, height, and area of clouds and storms, the phenomena and utility of thunder-storms, and the principal known facts in reference to the electricity of the atmosphere and earth, and the lightning discharges which take place between them.

As a depository of interesting knowledge, this book commends itself unreservedly to the public. It is filled with information equally practicable and important on many subjects. It contains 180 pages, with 28 illustrations, and is neatly bound in cloth. The author will send it to any point, postage prepaid, on receipt of $1.00.

Reform in the Lightning Protection Business.

THE business of applying metallic conductors to buildings, etc., for the purpose of protecting them from lightning discharges, has been principally carried on by a class of wandering mechanics known as "Lightning-Rod Men," who have, however, conducted it in such a manner as to bring the vocation into bad repute, and cause the public to lose faith in lightning-conductors.

In order to effect a proper reform and improvement in the lightning protection business, and enable property owners to obtain absolute protection from lightning at a reasonable expense, arrangements will be made with electricians, architects, builders, tinsmiths, plumbers, fire insurance companies, and others interested, for the proper introduction of the improved system of lightning-conductors herein described, which has been patented in the United States and Canada. None but competent and reliable mechanics will be selected to apply the said system of conductors to buildings, etc.

OPINIONS OF PROMINENT ELECTRICIANS, SCIENTISTS, AND JOURNALS.

THE following are selected from a large number of favorable opinions that have been given on Spang's Treatise on Lightning Protection and Improved System of Lightning-Conductors.

From Thos. A. Edison, Menlo Park, N. J., who is known as an eminent Electrician and the greatest Inventor of the age.

Mr. Spang is the best authority in this country on the subject of lightning protection.

From George B. Prescott, Electrician Western Union Telegraph Company.

I trust that the work will aid in bringing about a much needed reform in the matter of which it treats.

The methods of protection recommended are simple and comparatively inexpensive, and may be practically carried out by any intelligent mechanic, while at the same time they would without doubt prove an effective safeguard, as the principles upon which they are based are in accordance with the known laws which govern the accumulation and discharge of atmospheric electricity.

From the "Journal of the Telegraph" (the principal American electrical journal).

Mr. Spang, who is known as an able electrician as well as practical telegrapher, has devoted much time and study to the subject of efficient protection against the effects of atmospheric electrical discharges, the results of which are presented in this publication, which is by far the best work that has been published on this important subject.

We fully agree with the author that a system of conductors thus arranged (referring to the employment of rain-pipes, etc., with perforated iron pipes) would unquestionably afford absolute immunity from damage to persons or property from lightning in a building protected by them, and this at a much less expense than is incurred by the erection of the worthless, and in most cases absolutely dangerous contrivances with which ignorant and unprincipled agents have covered houses and other buildings without number in every town and village in the land.

From Latimer Clark, London, England, a distinguished Electrician and President of the English Society of Telegraph Engineers.

It is beyond all question the best and most complete book on the subject I have seen. I am very glad to see that you expose the fallacy of pointed lightning protectors. It is true that points do no harm, but I quite agree with you

that they also do no particular good, and I think you have done good service in stating the fact so clearly.

From Prof. S. F. Baird, Secretary Smithsonian Institution, Washington, D. C.

I shall take pleasure in commending the work to the attention of all persons interested.

From Prof. G. F. Barker, University of Pennsylvania, Philadelphia.

It is altogether the best book issued on the subject. The plan of protection proposed is founded on correct principles, and will be effective.

From Henry Van Hœvenbergh, Electrician Atlantic and Pacific Telegraph Company.

I consider buildings protected according to the plans suggested as nearly perfectly safe as can be accomplished by human foresight and experience.

From Geo. G. Ward, Superintendent Direct Cable Company, New York.

I consider your system of lightning-conductors an excellent one.

From C. T. Sellers, late Superintendent Philadelphia, Reading, and Pottsville Telegraph Company.

The employment of a metal roof and its rain-pipes, with the improved earth terminal, as suggested, will effect absolute protection, and if generally adopted, damage to buildings by lightning would become a thing almost unknown.

From S. D. Field, Electrician, San Francisco, Cal.

The use of perforated iron pipes as earth terminals for lightning-conductors, is a step in the right direction.

From Geo. F. Milliken, Electrician, Boston, Mass.

A work of extraordinary merit; highly entertaining and instructive.

From Prof. John Wise, the Veteran American Aeronaut and Meteorologist.

It contains all that can be said with any degree of certainty in reference to lightning protection. The author is doing the age good service in exposing the quackery of lightning-rod erection.

From the "Manufacturer and Builder."

We recommend the book highly to all who may be interested in this subject, such as architects, builders, tinsmiths, gas-fitters, manufacturers, farmers, and property owners. It is, in fact, the first book of this kind which ever came into our hands in which the author has shown that he understands the subject.

From the "Scientific American."

The work will be found useful in many respects, and will no doubt be fully appreciated by all who may have occasion to consult it.

From the "Operator" (a telegraphic journal).

A standard work, and should have a place in every scientific library.

From the "American Exchange and Review" (an insurance journal).

We can heartily commend this work as calculated to produce good results. There is no waste of printing in the issue of this book.

From the "Cultivator and Country Gentleman."

The book is a good, sound instructor, and contains a large fund of interesting matter.

From the "Christian Union" (Henry Ward Beecher's paper).

A sensible book on a subject which has occasioned more wild speculation than any other, excepting perpetual motion.

From the "Reading (Penna.) Times and Dispatch."

Mr. Spang is thoroughly conversant with the subject on which he has written such an admirable treatise. It is written in a popular vein, while the language is such as to render the subject familiar and enable the reader, whether learned or unlearned, to understand the author's meaning.

From the "Cleveland Herald."

A conscientious study of the work will fill with misgivings the minds of many persons who had rested easy during thunder-storms, in the conviction that their property was perfectly protected against lightning.

From the "Philadelphia Inquirer."

If only for one thing, the author of this book deserves well of his country, for, were his ideas acted upon, the lightning-rod man would be abolished from our midst. Mr. Spang does not pin his faith to lightning-rods. His idea is that the electric fluid can be made harmless in another way. That way is too elaborate and wonderful to explain here, but in the book it is expounded with much clearness and forcible argument.

From the "Railway Age."

The book must become authority on the subject of which it so ably treats.

From Jas. Gamble, Genl. Supt. Western Union Telegraph Company, San Francisco.

I should feel much safer, during a thunder-storm, in a building with the entire roof surface of metal properly connected with the earth, than with half a dozen lightning-rods over it.

From E. A. Hill, Electrician, Chicago.

I regard your system as the best, and when properly carried out will give very efficient protection from the destructive effects of lightning.

From the "Columbia (N. Y.) Spectator."

It is a work that has long been needed, and ably supplies the want of knowledge experienced by all classes of men on this subject.

From Hugh Neilson, Superintendent Dominion Telegraph Company, Toronto, Canada.

I cannot find anything in your work with which I do not thoroughly agree.

From Angus Grant, Electrician, Montreal, Canada.

It is the only practical work I have ever seen on the subject, and ought to revolutionize the lightning-rod business.

From the "Prairie Farmer."

The book gives the rational and scientific methods of protection against lightning, and is well worth the price asked for it.

From W. J. Holmes, Supt. Telegraph, Erie Railroad Company, New York.

Your method of protecting buildings by the employment of metal roofs, gutters, and leaders connected with the earth, as suggested, will prove effectual.

From E. P. Wright, Electrician, Cleveland, Ohio.

I consider your system of lightning protection the best that has yet been devised.

From the "North-Western-Lumberman."

The author brings to his work the experience of over eighteen years, of which he has left many evidences in the pages of this interesting volume.

From the "Polytechnic Review."

It is unquestionably the best treatise on the subject of lightning protection that has been produced.

Issued April, 1877.

A PRACTICAL TREATISE

ON

Lightning Protection.

By HENRY W. SPANG,

Reading, Pa.

180 Pages, with 28 Illustrations.

12mo, CLOTH, $1.00.

The Author will send Copies by Mail, postage prepaid, on receipt of Price

It contains general information on the subject, and tre ain not only upon the protection of buildings, but also of ships, oil-tanks, steam-boilers, wooden bridges, telegraph poles, etc. explains the principal technical terms used in the elec- science, and the properties of the different kinds of ty, and also gives the formation, height, and area and storms, the phenomena and utility of thunder- d the principal known facts in reference to the f the atmosphere and earth and the lightning hich take place between them.

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